

# EARTHQUAKE LOSS ESTIMATION METHODOLOGY

# HAZUS<sup>®</sup>99

Service Release 2 (SR2)

## Technical Manual

*Developed by:*

Federal Emergency Management Agency  
Washington, D.C.

*Through agreements with:*

National Institute of Building Sciences  
Washington, D.C.

## PREFACE

Earthquakes pose a threat to life and property in 45 states and territories. As the United States has become more urbanized, more frequent smaller earthquakes in the 6.5 to 7.5 Magnitude range now have the potential of causing damage equal to or exceeding the estimated \$40 billion from the 1994 Northridge earthquake. Earthquakes in urban areas, such as Kobe, Japan and Izmit, Turkey, are grim reminders of the kind of damage that may result from larger earthquakes, like the San Francisco event of 1906 and eastern events that occurred in New Madrid in 1811-12.

The Federal Emergency Management Agency is committed to mitigation as a means of reducing damages and the social and economic impacts from earthquakes. FEMA, under agreements with the National Institute of Building Sciences, has developed HAZUS® (HAZUS® stands for "Hazards U.S."), a standard, nationally applicable methodology for assessing earthquake risk. HAZUS® was first released in 1997, followed by three subsequent releases, HAZUS®99 and two HAZUS®99 service releases, HAZUS®99-SR1 and HAZUS®99-SR2. With each new edition, significant enhancements have been added to increase the capabilities of HAZUS®. In HAZUS®99, a disaster response application was added to facilitate the use of HAZUS® in the immediate post-disaster environment. In the most recent edition, HAZUS®99-SR2, an Advanced Engineering Building Module (AEBM) has been implemented to enable high-end users to explicitly conduct building-specific or portfolio-specific loss estimation. HAZUS®97, HAZUS®99, and the two service releases of this earthquake loss estimation methodology, represent the dedicated efforts of more than 130 nationally recognized earthquake and software professionals.

FEMA is making HAZUS® available to all states and communities and the private sector. Communities find HAZUS® to be a valuable tool in promoting a broader understanding of potential earthquake losses and in helping to build a community consensus for disaster loss prevention and mitigation.

Since the first release of HAZUS®, FEMA has been expanding the capability of HAZUS® by initiating loss estimation models for flood and hurricane hazards. The HAZUS Flood Model and a Preview Hurricane Model are being readied for release in 2002.

FEMA is pleased to offer this manual to state and local users.

## FOREWORD

The work that provided the basis for this publication was supported by funding from the Federal Emergency Management Agency (FEMA) under agreements with the National Institute of Building Sciences. The substance and findings of that work are dedicated to the public. NIBS is solely responsible for the accuracy of the statements and interpretations contained in this publication. Such interpretations do not necessarily reflect the views of the Federal Government.

The National Institute of Building Sciences (NIBS) is a non-governmental, non-profit organization, authorized by Congress to encourage a more rational building regulatory environment, to accelerate the introduction of existing and new technology into the building process and to disseminate technical information.

Copies of this report are available through the Federal Emergency Management Agency. For information contact FEMA @ [www.fema.gov/hazus](http://www.fema.gov/hazus) or:

FEMA Distribution Center  
P.O. Box 2012  
Jessup, Maryland 20794-2012  
Tel.: 1 800-480-2520  
Fax: 301-362-5335

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## MESSAGE TO USERS

HAZUS is designed to produce loss estimates for use by federal, state, regional and local governments in planning for earthquake risk mitigation, emergency preparedness, response and recovery. The methodology deals with nearly all aspects of the built environment, and a wide range of different types of losses. Extensive national databases are embedded within HAZUS, containing information such as demographic aspects of the population in a study region, square footage for different occupancies of buildings, and numbers and locations of bridges. Embedded parameters have been included as needed. Using this information, users can carry out general loss estimates for a region. The HAZUS methodology and software are flexible enough so that locally developed inventories and other data that more accurately reflect the local environment can be substituted, resulting in increased accuracy.

Uncertainties are inherent in any loss estimation methodology. They arise in part from incomplete scientific knowledge concerning earthquakes and their effects upon buildings and facilities. They also result from the approximations and simplifications that are necessary for comprehensive analyses. Incomplete or inaccurate inventories of the built environment, demographics and economic parameters add to the uncertainty. These factors can result in a range of uncertainty in loss estimates produced by HAZUS, possibly *at best* a factor of two or more.

The methodology has been tested against the judgement of experts and, to the extent possible, against records from several past earthquakes. However, limited and incomplete data about actual earthquake damage precludes complete calibration of the methodology. Nevertheless, when used with embedded inventories and parameters, HAZUS has provided a credible estimate of such aggregated losses as the total cost of damage and numbers of casualties. HAZUS has done less well in estimating more detailed results - such as the number of buildings or bridges experiencing different degrees of damage. Such results are depend heavily upon accurate inventories. HAZUS assumes the same soil condition for all locations, and this has proved satisfactory for estimating regional losses. Of course, the geographic distribution of damage may be influenced markedly by local soil conditions. In the few instances where HAZUS has been partially tested using actual inventories of structures plus correct soils maps, it has performed reasonably well.

Users should be aware of the following specific limitations:

- While HAZUS can be used to estimate losses for an individual building, the results must be considered as average for a group of similar buildings. It is frequently noted that nominally similar buildings have experienced vastly different damage and losses during an earthquake.
- When using embedded inventories, accuracy of losses associated with lifelines may be less than for losses from the general building stock. The embedded databases and assumptions used to characterize the lifeline systems in a study region are necessarily incomplete and oversimplified.

- Based on several initial studies, the losses from small magnitude earthquakes (less than M6.0) centered within an extensive urban region appear to be overestimated.
- Because of approximations in modeling of faults in California, there may be discrepancies in motions predicted within small areas immediately adjacent to faults.
- There is considerable uncertainty related to the characteristics of ground motion in the Eastern U.S. The embedded attenuation relations in HAZUS, which are those commonly recommended for design, tend to be conservative. Hence use of these relations may lead to overestimation of losses in this region, both for scenario events and when using probabilistic ground motion.
- As yet, there have not been adequate tests for the following features of HAZUS:
  - Effects of liquefaction and landsliding
  - Debris generation
  - Indirect economic losses

HAZUS should still be regarded as a work in progress. Additional damage and loss data from actual earthquakes and further experience in using the software will contribute to improvements in future releases. To assist us in further improving HAZUS, users are invited to submit comments on methodological and software issues by letter, fax or e-mail to:

Philip Schneider  
 National Institute of Building Sciences  
 1201 L Street, N.W.  
 Washington, D.C. 20005  
 Fax: 202-289-1092  
 E-mail: pschneider@nibs.org

Claire Drury  
 Federal Emergency Management Agency  
 500 C Street, SW  
 Washington DC, 20472  
 Fax: 202-646-2577  
 E-mail: claire.drury@fema.gov

## ACKNOWLEDGMENTS

### **HAZUS97**

#### ***Earthquake Committee***

*Chairman, Robert V. Whitman, Massachusetts Institute of Technology, Cambridge, Massachusetts  
Roger Borcherdt, U.S. Geological Survey, Menlo Park, California  
David Brookshire, University of New Mexico, Albuquerque, New Mexico  
Richard Eisner, California Office of Emergency Services, Oakland California  
William Holmes, Rutherford & Chekene, San Francisco, California  
Robert Olson, Robert Olson & Associates, Inc., Sacramento, California  
Michael O'Rourke, Rensselaer Polytechnic Institute, Troy, New York  
Robert Reitherman, California Universities for Research in Earthquake Engineering, Richmond, California*

#### ***Project Oversight Committee***

*Chairman, Henry J. Lagorio,, University of California at Berkeley, Berkeley, California  
Arrietta Chakos, City of Berkeley, Berkeley, California  
Donald H. Cheu, Kaiser Permanente, South San Francisco, California  
Tom Durham, Central United States Earthquake Consortium, Memphis, Tennessee  
Jerry A. Foster, ISO Commercial Risk Services, Inc., Scottsdale, Arizona  
Edward Fratto, New England States Emergency Consortium, Wakefield, Massachusetts  
Steven French, Georgia Institute of Technology, Atlanta, Georgia  
Steve Ganz, Western States Seismic Policy Council, San Francisco, California  
Alan Goldfarb, Berkeley, California  
Jack Harrald, George Washington University, Washington, D.C.  
Thomas Kinsman, City of Seattle, Construction & Land Use, Seattle, Washington  
George Mader, Spangle Associates, Portola Valley, California  
Shirley Mattingly, FEMA Region 9, San Francisco, California  
Kent Paxton, San Mateo Area Office Emergency Services, Redwood City, California  
John Smith, Massachusetts Emergency Management Agency, Framingham, Massachusetts  
Douglas Smits, City of Charleston, Charleston, South Carolina  
J. Carl Stepp, Austin, Texas  
Gerry Uba, Emergency Management Program, Metro, Portland, Oregon*

#### ***Earthquake Loss Estimation Methodology Assessments, Development and Calibrations***

##### ***Risk Management Solutions, Inc., Menlo Park, California***

*Scott Lawson, Project Manager; Mourad Bouhafs, Software Manager; Fouad Bendimerad, Jawhar Bouabid, Fouad Bouhafs, Jason Bryngelson, Weimen Dong, Surya Gunturi, Dina Jabri, Guy Morrow, Hemant Shah, Chessy Si, Pane Stojanovski*

##### ***Risk Management Solutions, Inc, Consultants:***

*Charles Kircher, Technical Manager, Kircher & Associates, Mountain View, CA; Thalia Anagnos, Assistant Project Manager, and Guna Selvaduray, San Jose State University, San Jose, CA; Chris*

*Arnold, Building Systems Development, Palo Alto, CA; Nesrin Basoz, K2 Technologies Inc; Catalino Cecilio and Martin McCann, Jack Benjamin & Associates; Hal Cochrane, Mahmoud Khater, EQE; John Mander, SUNY Buffalo; John McKean, Jerry Steenson and Bob Young, Colorado State University; Bryce Connick, Tom Desmond, John Eidinger, Bruce Maison and Dennis Ostrom, G&E Engineering, Oakland, CA; John Egan and Maurice Power, Geomatrix, San Francisco, CA; Gerald Horner, Horner & Associates; Onder Kustu, Oak Engineering, Belmont, CA; Gregory Luth and John Osteraas, Failure Analysis Associates, Menlo Park, CA; Farzad Namien, Consultant; Aladdin Nassar, Consultant; Jeanne Perkins, Association of Bay Area Governments, Oakland, CA; Claire Rubin, Claire Rubin & Associates, Arlington, VA; Jean Savy, Lawrence Livermore Laboratory; Paul Sommerville, Woodward-Clyde, Pasadena, CA; Fred Webster, Consultant, Menlo Park, CA; Felix Wong, Weidlinger Associates*

#### ***California Universities for Research in Earthquake Engineering***

*A. H-S Ang, University of California, Irvine, CA; Jonathan Bray, Armen Der Kiureghian, Jack Moehle, Raymond Seed and Brady Williamson, University of California, Berkeley, CA; Peter Gordon, Harry Richardson, University of Southern California, Los Angeles, CA; David Keefer, U.S. Geological Survey, Menlo Park, CA; Anne Kiremidjian, Helmut Krawinkler and Haresh Shah, Stanford University, Stanford, CA*

#### ***Portland Pilot Study***

##### ***Dames & Moore, Inc.***

*Seattle, Washington: C.B. Crouse, Project Manager; Donald Ballantyne, Project Manager; Linda Noson, Assistant Project Manager; William Heubach, Greg Lammers, Eugene Trahern, Kenneth Winnick  
San Francisco, California: Jim Hengesh; Los Angeles, California: Alan Porush; Portland, Oregon: Douglas Schwarm; Santa Ana, California: Craig Tillman*

##### ***Dames & Moore Consultants:***

*Carl Batten, ECO Northwest, Portland, OR; James Beavers, Mitigation Solutions Technology, Inc., Oakridge, TN; Grant Davis, KPFF Consulting Engineers, Portland, OR; Matthew Katinsky and John Schlosser, Schlosser & Associates, Seattle, WA*

#### ***Boston Pilot Study***

##### ***EQE International***

*Irvine, California: Ron Eguchi, Principal-in-Charge, Paul Flores, Project Manager, Ted Algermissen, R. Augustine, Neil Blais, Don Ballantyne, Stephanie Chang, Kenneth Campbell, Ronald Hamburger, Jim Johnson, Mayasandra Ravindra, Tom Roche, Michael Rojanski, Charles Scawthorn, Hope Seligson, Solveig Thorvald; New Hampshire: Paul Baughman, James White*

##### ***EQE International Consultants:***

*Sam Liao and Steve Line, Parsons Brinckerhoff, Boston, MA; Adam Rose, Penn State University, University Park, PA*

#### ***Federal Emergency Management Agency, Mitigation Directorate, Washington, D.C.***

*Gil Jamieson, Risk Assessment Branch Chief (1994 -1998);, John Gamble, Program Development Branch Chief (1992 - 1993);, Claire Drury, Project Officer (1996 - present);, Fred Sharrocks, Project Officer (1994 - 1996);, Michael Mahoney, Project Officer (1992 - 1993).*

***U.S. Geological Survey, Reston, Virginia***

*Paula Gori (1995 - 1998), John Filson (1992 - 1993)*

***National Institute of Building Sciences, Washington, D.C.***

*Philip Schneider, Director, Earthquake Loss Estimation Program; Bruce E. Vogelsinger, Vice-President; Baldev Sikka, Administrative Assistant*

## ACKNOWLEDGMENTS

### **HAZUS99**

#### ***Earthquake Committee***

*Chairman, Robert V. Whitman, Massachusetts Institute of Technology, Cambridge, Massachusetts  
Roger Borcherdt, U.S. Geological Survey, Menlo Park, California  
David Brookshire, University of New Mexico, Albuquerque, New Mexico  
Richard Eisner, California Office of Emergency Services, Oakland California  
William Holmes, Rutherford & Chekene, San Francisco, California  
Henry J. Lagorio, University of California at Berkeley, Berkeley, California  
Robert Olson, Robert Olson & Associates, Inc., Sacramento, California  
Michael O'Rourke, Rensselaer Polytechnic Institute, Troy, New York  
Robert Reitherman, California Universities for Research in Earthquake Engineering, Richmond, California*

#### ***Transportation Lifeline Subcommittee***

*Chairman, Michael O'Rourke, Rensselaer Polytechnic Institute, Troy, New York  
David Brookshire, University of New Mexico, Albuquerque, New Mexico  
Ian Friedland, MCEER, SUNY @ Buffalo, Buffalo, NY  
John Mander, SUNY @ Buffalo, Buffalo, NY  
Robert V. Whitman, Massachusetts Institute of Technology, Cambridge, Massachusetts*

#### ***Utility Lifeline Subcommittee***

*Chairman, Michael O'Rourke, Rensselaer Polytechnic Institute, Troy , New York  
William Holmes, Rutherford & Chekene, San Francisco, California  
Thomas O'Rourke, Cornell University, Ithaca, New York  
Robert Reitherman, California Universities for Research in Earthquake Engineering, Richmond, California  
William Savage, Pacific Gas & Electric Co., San Francisco, California*

### ***Earthquake Loss Estimation Methodology Assessments, Development and Calibrations***

#### ***Risk Management Solutions, Inc., Menlo Park, California***

*Scott Lawson, Project Manager; Mourad Bouhafs, Software Manager; Fouad Bendimerad, Jawhar Bouabid, Fouad Bouhafs, Jason Bryngelson, Weimen Dong, Dina Jabri, Guy Morrow, Hemant Shah, Chessy Si, Pane Stojanovski, Anju Gupta, Laurie Johnson, Thanksala Prasana, Shannon McCay, Scott Martin, Louise Wilcox*

#### ***NIBS Consultants:***

*Nesrin Basoz, K2 Technologies Inc, San Jose, California; John Mander SUNY@ Buffalo, Buffalo, New York; Mahmoud Khater, EQE International, Oakland, California; Federico Waisman, EQE International, Oakland, California; E.V. Leyendecker, USGS, Denver, Colorado*

***Federal Emergency Management Agency, Mitigation Directorate, Washington, D.C.***

*Margaret Lawless, Program Assessment and Outreach Division Director (1998-1999); Cliff Oliver, Program Policy and Assessment Branch Chief (1998-present); Claire Drury, Project Officer (1996 - present); Stuart Nishenko (1998 - present).*

***National Institute of Building Sciences, Washington, D.C.***

*Philip Schneider, Director, Multihazard Loss Estimation Program; Bruce E. Vogelsinger, Vice-President; John Boyer, Project Manager; Barbara Schauer, Project Manager*

## ACKNOWLEDGMENTS

### ***HAZUS99-SR1***

#### ***Earthquake Committee***

*Chairman, William Holmes, Rutherford & Chekene, San Francisco, California  
Roger Borcherdt, U.S. Geological Survey, Menlo Park, California  
David Brookshire, University of New Mexico, Albuquerque, New Mexico  
Richard Eisner, California Office of Emergency Services, Oakland California  
Henry J. Lagorio, University of California at Berkeley, Berkeley, California  
Robert Olson, Robert Olson & Associates, Inc., Sacramento, California  
Michael O'Rourke, Rensselaer Polytechnic Institute, Troy, New York  
Robert Reitherman, California Universities for Research in Earthquake Engineering, Richmond, California  
Robert V. Whitman, Massachusetts Institute of Technology, Cambridge, Massachusetts*

#### ***Software Revisions***

***Durham Technologies, Inc.***  
*Scott Lawson, Mourad Bouhafs, Jawhar Bouabid*

#### ***Federal Emergency Management Agency, Mitigation Directorate, Washington, D.C.***

*Cliff Oliver, Program Policy and Assessment Branch Chief (1998-present); Claire Drury, Project Officer (1996 - present); Stuart Nishenko (1998 - present)*

#### ***National Institute of Building Sciences, Washington, D.C.***

*Philip Schneider, Director, Multihazard Loss Estimation Program; John Boyer, Project Manager; Barbara Schauer, Project Manager*

## ACKNOWLEDGMENTS

### **HAZUS99 SR-2**

#### ***Earthquake Committee***

*Chairman, William Holmes, Rutherford & Chekene, San Francisco, California  
Roger Borcherdt, U.S. Geological Survey, Menlo Park, California  
David Brookshire, University of New Mexico, Albuquerque, New Mexico  
Richard Eisner, California Office of Emergency Services, Oakland California  
Robert Olson, Robert Olson & Associates, Inc., Sacramento, California  
Michael O'Rourke, Rensselaer Polytechnic Institute, Troy, New York  
Henry J. Lagorio, University of California at Berkeley, Berkeley, California  
Robert Reitherman, Consortium of Universities for Research in Earthquake Engineering, Richmond, California  
Robert V. Whitman, Massachusetts Institute of Technology, Cambridge, Massachusetts*

#### ***Building Damage Subcommittee***

*William Holmes, Rutherford & Chekene, San Francisco, California  
Robert V. Whitman, Massachusetts Institute of Technology, Cambridge, Massachusetts*

#### ***Casualties Subcommittee***

*Chairman, Robert Reitherman, Consortium of Universities for Research in Earthquake Engineering, Richmond, California  
Richard Eisner, California Office of Emergency Services, Oakland California  
William Holmes, Rutherford & Chekene, San Francisco, California  
Robert Olson, Robert Olson & Associates, Inc., Sacramento, California  
Henry J. Lagorio, University of California at Berkeley, Berkeley, California*

#### ***Methodology Revisions***

**Kircher & Associates**  
*Charles Kircher  
San Jose State University Foundation  
Thalia Anagnos*

#### ***Software & Methodology Revisions***

**Durham Technologies, Inc.**  
*Scott Lawson, Mourad Bouhafs, Jawhar Bouabid*

#### ***Federal Emergency Management Agency, Mitigation Directorate, Washington, D.C.***

*Chris Doyle, Building Sciences and Technology Acting Branch Chief (2001); Ugo Morelli, Building Sciences and Technology Acting Branch Chief (2001); Cliff Oliver, Program Policy and Assessment Branch Chief (1998-2001); Claire Drury, Project Officer (1996 - present); Stuart Nishenko (1998 - 2001)*

#### ***National Institute of Building Sciences, Washington, D.C.***

*Philip Schneider, Director, Multihazard Loss Estimation Methodology Program; Barbara Schauer, Project Manager*

## WHAT IS NEW IN HAZUS99-SR2?

- An Advanced Engineering Building Module (AEBM) has been implemented to enable high-end users to explicitly conduct building-specific or portfolio-specific loss estimation. A manual is provided to guide users in implementation of the AEBM and to describe underlying theory and concepts.
- In the Casualties Module, relationships between damage and casualties and the injury classification scale have been revised. Capability has been added for calculating casualties in the outdoors. Details of the updated methodology can be found in Chapter 13 of the *Technical Manual*.
- Occupancy mapping data for the State of California has been updated.

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